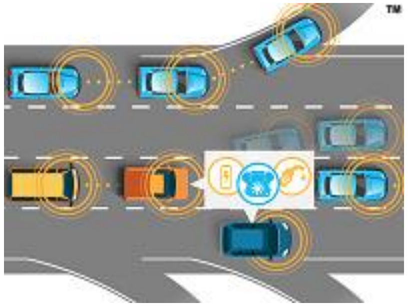
CHANGING WHAT'S POSSIBLE

# NEXTCAR – Next Generation Energy Technologies for Connected and Automated On-Road Vehicles

**2020 Annual Program Review**

**May 12, 2020**



U.S. DEPARTMENT OF ENERGY

# NEXTCAR Annual Review - Housekeeping

- This webinar can support up to **1000 participants**. If for some reason we experience latency issues, we will hold the meeting with critical team members only (and NOT more than 5 critical people per team).
- **Only the presenter MUST turn ON their video**. The remaining attendees MUST NOT turn on their video feature. At the beginning of the meeting, no one except Chris will turn ON their videos.
- We will be driving the slides from Gokul Vishwanathan's computer. We will **NOT pass the presenter** privileges to any presenter. Please do NOT attempt to steal or request presenter privilege.
- Everyone except the presenter **MUST be on mute**. Those passively participating in the meeting (i.e. everyone except the PIs, presenters and ARPA-E team) MUST NOT turn on their microphones.
- Questions CANNOT be asked **<u>verbally</u>** during or after the presentation since everyone will be on mute. Please use the CHAT feature to post your questions to **<u>Reid Heffner only</u>** using the private chat feature (and NOT to the entire audience) either during the presentation or after the presentation. Reid (Rusty) will act as the moderator for filtering pertinent questions. Q&A session and discussion will be held after all the project presentations.
- Presenters, PLEASE present your slides in the allotted time limit of **7 minutes.**

# Agenda

- Opening Remarks & Introduction – Chris Atkinson
- NEXTCAR Team Presentations
  - Michigan Tech. – Jeff Naber
  - GM – Chen-Fang Chang
  - SwRI – Scott Hotz or Sankar Rengarajan
  - OSU – Giorgio Rizzoni
  - UCB – Francesco Borrelli
  - University of Delaware – Andreas Malikopoulos
  - University of Michigan – Jing Sun
  - University of Minnesota – Will Northrop
  - UCR – Matt Barth
  - PSU – Sean Brennan
- Q&A and Discussion
- Concluding Remarks – Chris Atkinson and Mary Yamada

# ARPA-E and NEXTCAR Current Status

- ARPA-E – under full telework (since March)
- NEXTCAR teams
  - None currently have access to their vehicles
  - Plans for restarting? Yes, many plans…
- No Cost Extensions – until 12/31/2020 in many cases
- Budget adjustments – no information as yet
- Program Director transition – Marina Sofos, PhD.

# ARPA-E NEXTCAR Team


Chris Atkinson
Program Director

Marina Sofos
Program Director

Mary Yamada
Tech-to-Market Advisor

## Technical Support

Reid (Rusty) Heffner

Huthaifa Ashqar

Gokul Vishwanathan

## Programmatic Support

Whitney White

Ahmed Skaljic

# Marina Sofos, Program Director

- Almost 10 years with DOE managing R&D programs in energy efficiency technologies @ Advanced Manufacturing Office & Building Technologies Office
- Interests include sensors, controls & data analytics for energy efficiency
- Degrees in Materials Science & Engineering (Sc.B. Brown Univ, Ph.D. Northwestern Univ, Postdoc Argonne National Lab)

BROWN

Northwestern University

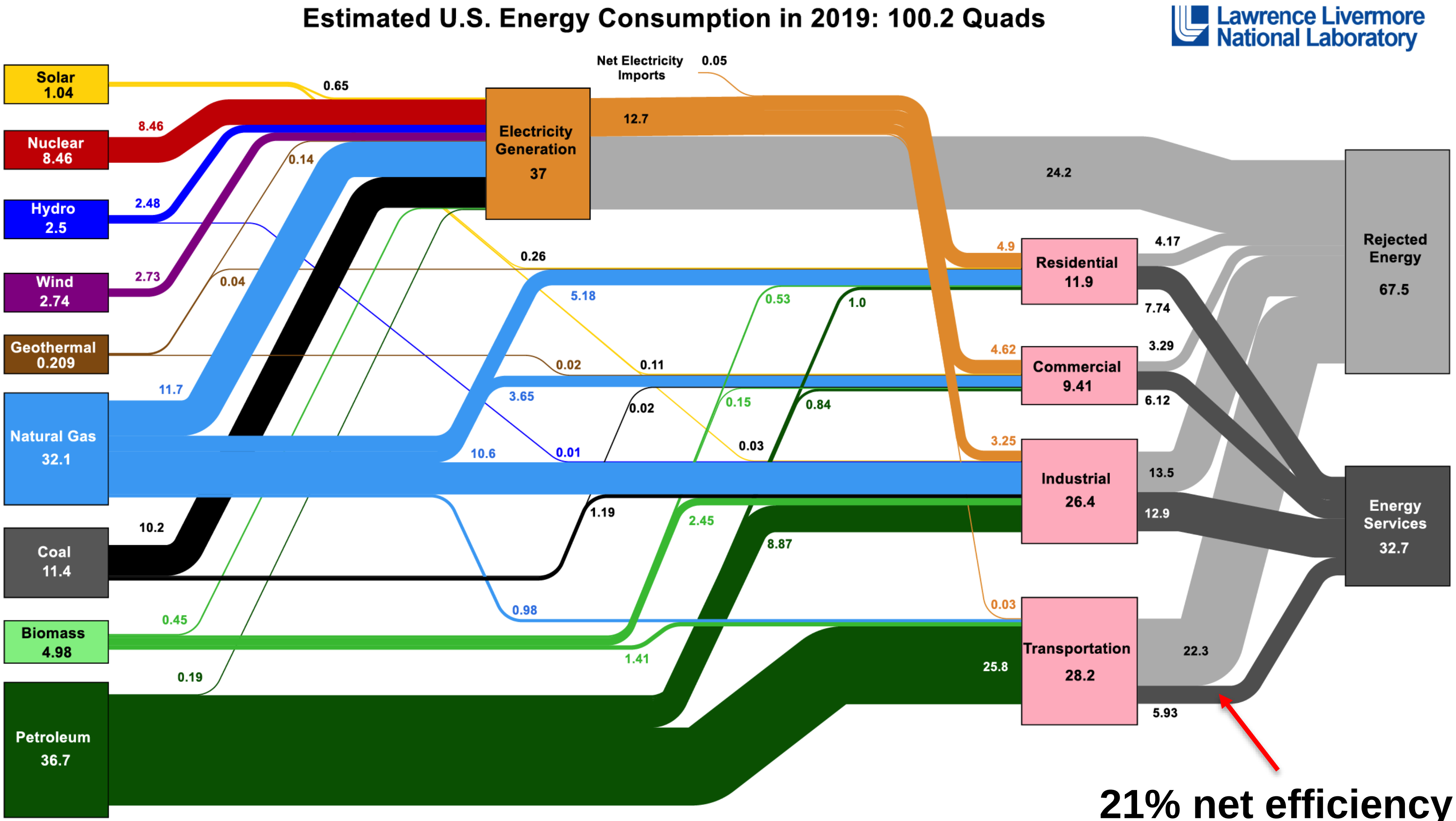
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Argonne NATIONAL LABORATORY

# ARPA-E’s Mission

**Mission:** To overcome long-term and high-risk technological barriers in the development of energy technologies

# Why is NEXTCAR important to ARPA-E?




**21% net efficiency**

Source: LLNL March, 2020. Data is based on DOE/EIA MER (2019). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

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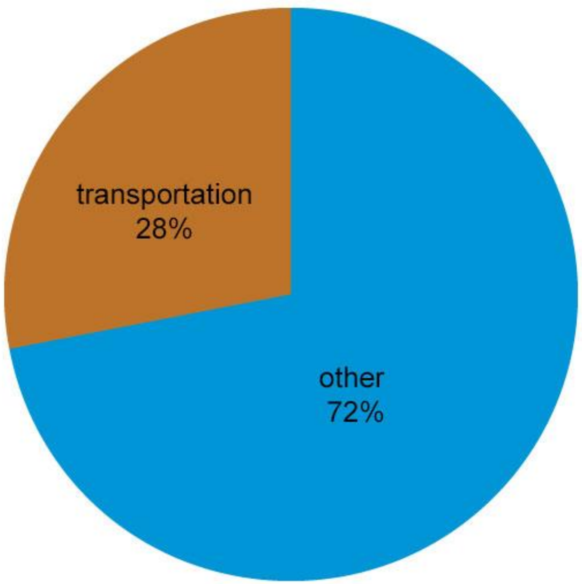
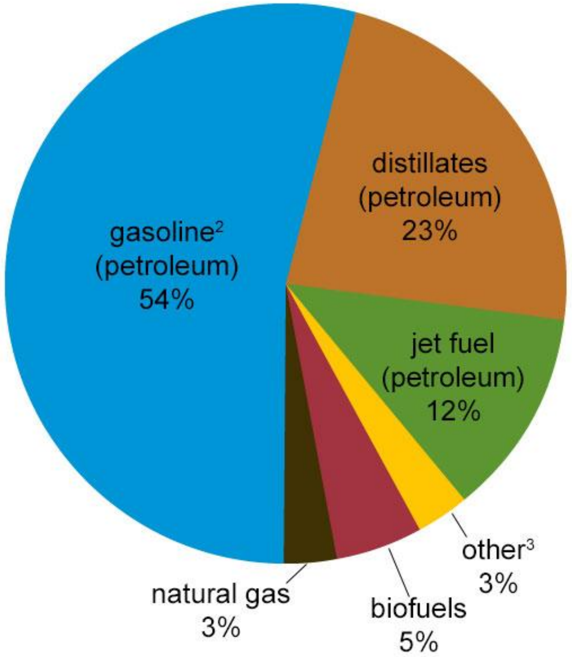
# Transportation Energy Usage

**Share of total U.S. energy used for transportation, 2018**




Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 2.1, April 2019, preliminary data

**U.S. transportation energy sources/fuels, 2018**[1]




[1] Based on energy content

[2] Motor gasoline and aviation gas; excludes ethanol

[3] Includes residual fuel oil, lubricants, hydrocarbon gas liquids (mostly propane), and electricity (includes electrical system energy losses).

Note: Sum of individual components may not equal 100% because of independent rounding.

Source: U.S. Energy Information Administration, *Monthly Energy Review,* Tables 2.5, 3.8c, and 10.2b, April 2019, preliminary data

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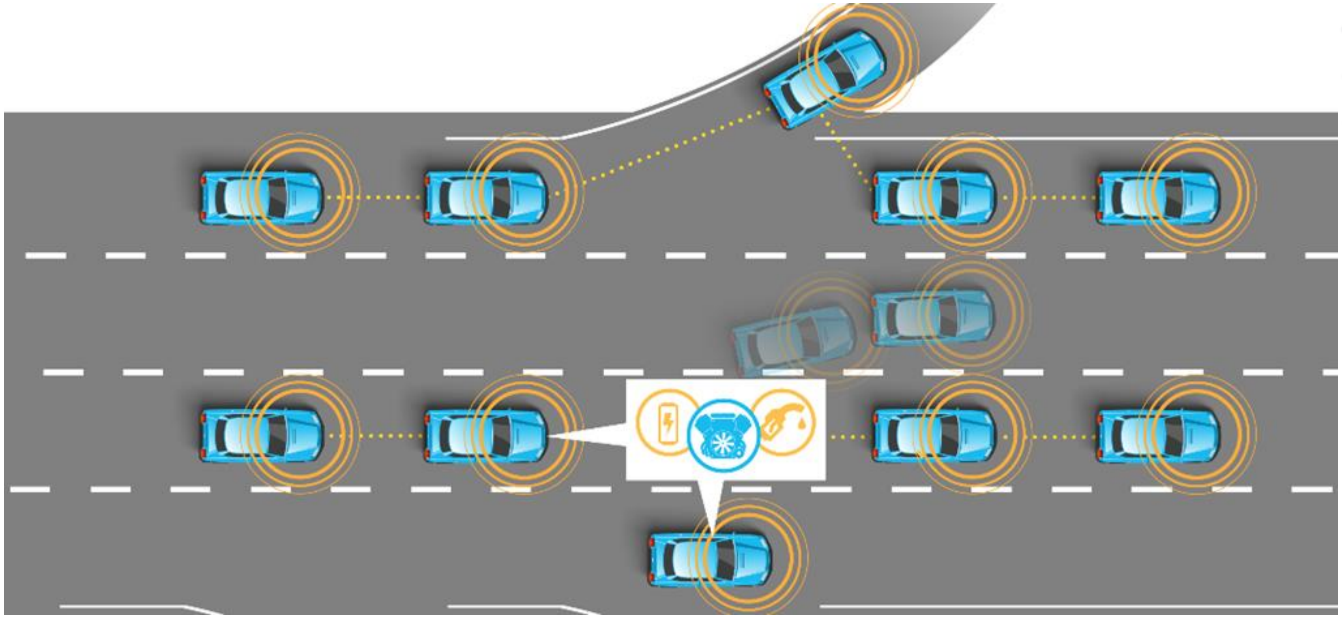
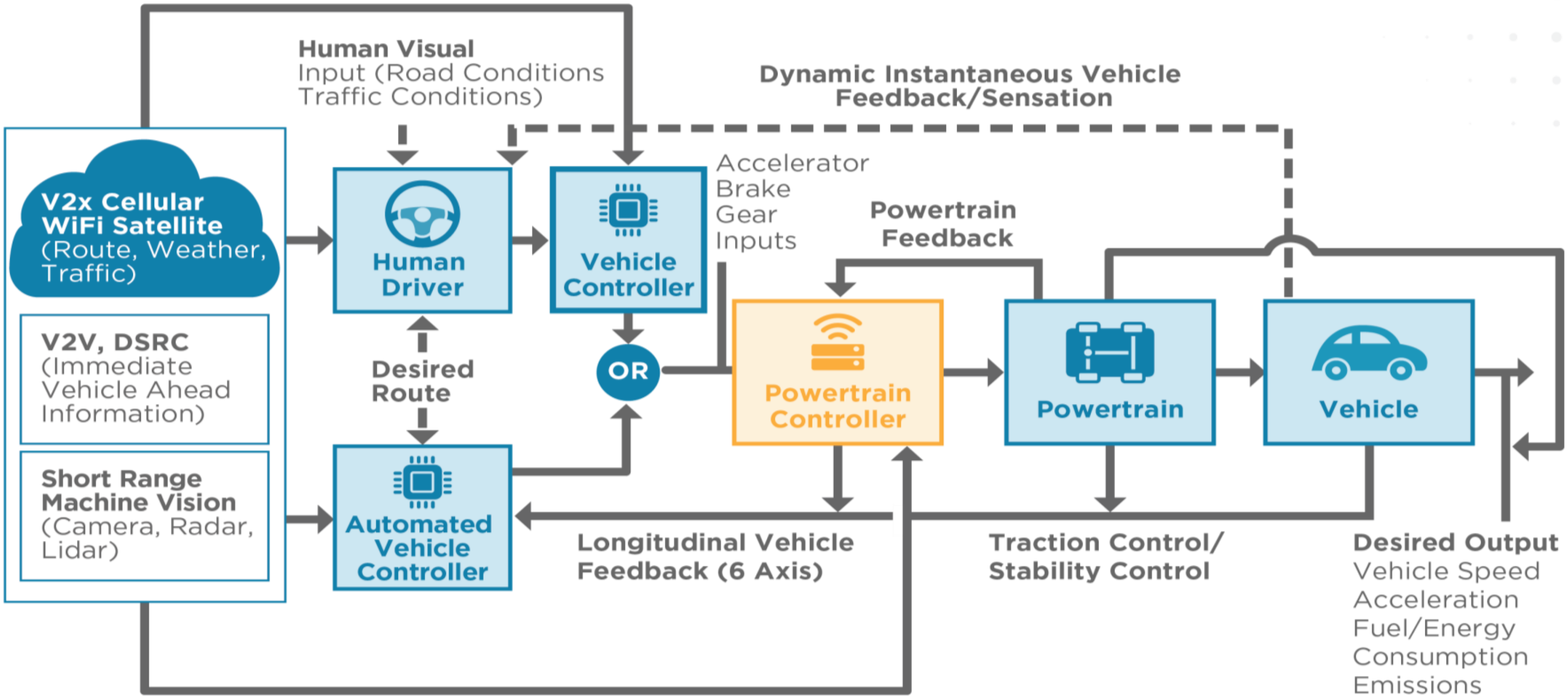
# ARPA-E NEXTCAR Program Motivation



**Facilitating energy-efficient L1-L3 CAV operation through connectivity and automation.**

**Using eco-routing, eco-driving, ecoAND, hybrid energy flow optimization, platooning and other connected and L1-L3 automation techniques to improve vehicle energy efficiency by 20%.**

# Future Powertrain and Vehicle Dynamic Control with NEXTCAR






ca. 2016

# NEXTCAR Portfolio

## Light Duty Vehicles

### Gasoline

*Inforich VD&PT Controls*

*Connected and Automated Control for Vehicle Dynamics and Powertrain Operation on a Light-Duty Multi-Mode Hybrid Electric Vehicle*

*Fuel Economy Optimization with Dynamic Skip Fire in a Connected and Automated Vehicle*

*Model Predictive Control for Energy-Efficient Maneuvering of Connected Autonomous Vehicles*

*Predictive Data-Driven Vehicle Dynamics and Powertrain Control – From ECU to the Cloud*

*Simultaneous Optimization of Vehicle and Powertrain Operation Using Connectivity and Automation*

*Integrated Power and Thermal Management for Connected and Automated Vehicles (iPTM-CAV) Through Real-Time Adaptation and Optimization*

## Medium Duty Vehicles

### Gasoline

*Cloud Connected Delivery Vehicle*

### Natural Gas

*Connected Eco-Bus: An Innovative Vehicle-Powertrain Eco Operation System for Efficient Plug-in Hybrid Electric Bus*

## Heavy Duty Vehicles

### Diesel

*Enabling high-efficiency operation through next-generation controls systems development for connected & automated class 8 trucks*

*Maximizing Vehicle Fuel Economy through the Real-Time, Collaborative, and Predictive Co-Optimization of Routing, Speed, and Powertrain Control*

# NEXTCAR Industry Ecosystem

**OEMs**

TOYOTA

GM

Cummins

HYUNDAI MOTOR GROUP

VOLVO

TRUCKS USA

**Tier-1 Suppliers**

BOSCH Invented for life

Delphi Technologies

APTIV

**System integrators, CAV service providers and others**

TULA

SENSYS networks

Peloton

US Hybrid

WORKHORSE

# External Stakeholders at 2019 Annual Review

**Government**

Office of
ENERGY EFFICIENCY & RENEWABLE ENERGY

NRC·CNRC

**OEMs**

FCA
FIAT CHRYSLER AUTOMOBILES

Ford
Go Further

TOYOTA
RESEARCH INSTITUTE

DAIMLER

**Tier-1 Suppliers and Equipment Manufacturers**

DENSO
Crafting the Core

Velodyne
LiDAR

Infineon

intel

Valeo

**Testing Services**

American Center for Mobility
CONNECTED. AUTOMATED. VALIDATED.

**Mobility Services**

lyft

**Energy Providers**

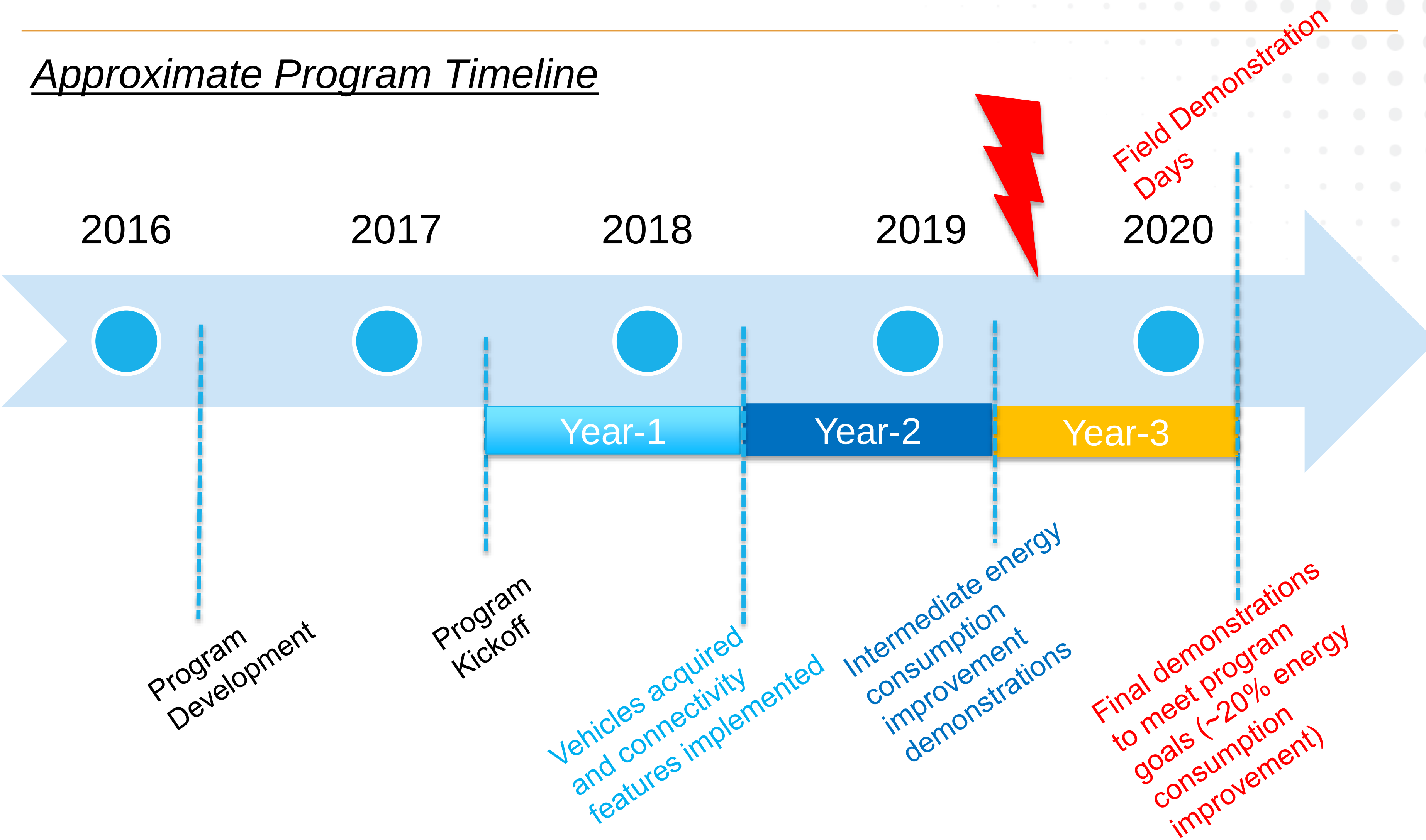
aramco

**NGO/Consultancy**

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

# NEXTCAR Timeline and Critical Milestones

<u>*Approximate Program Timeline*</u>

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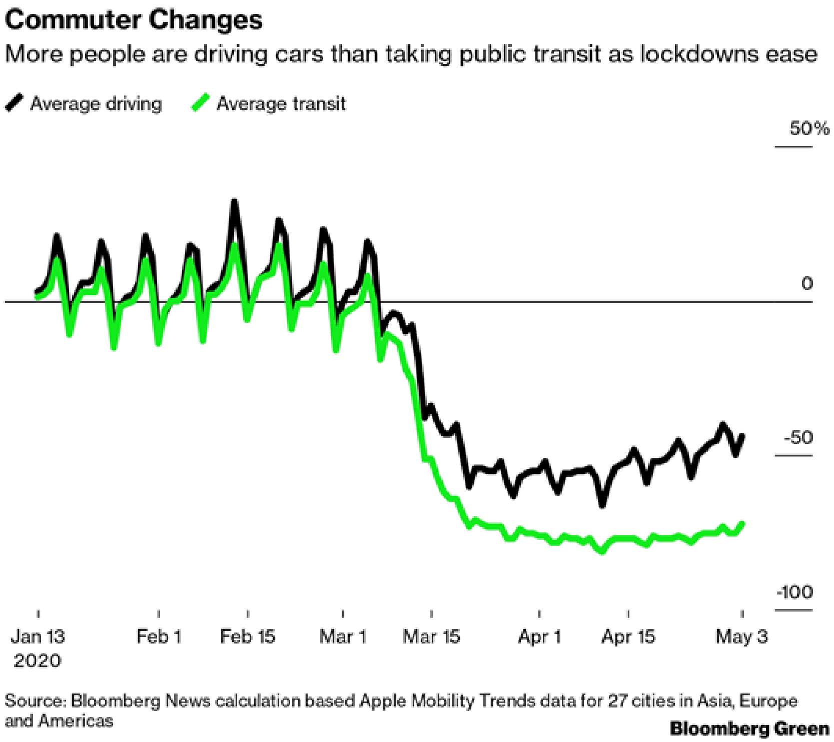
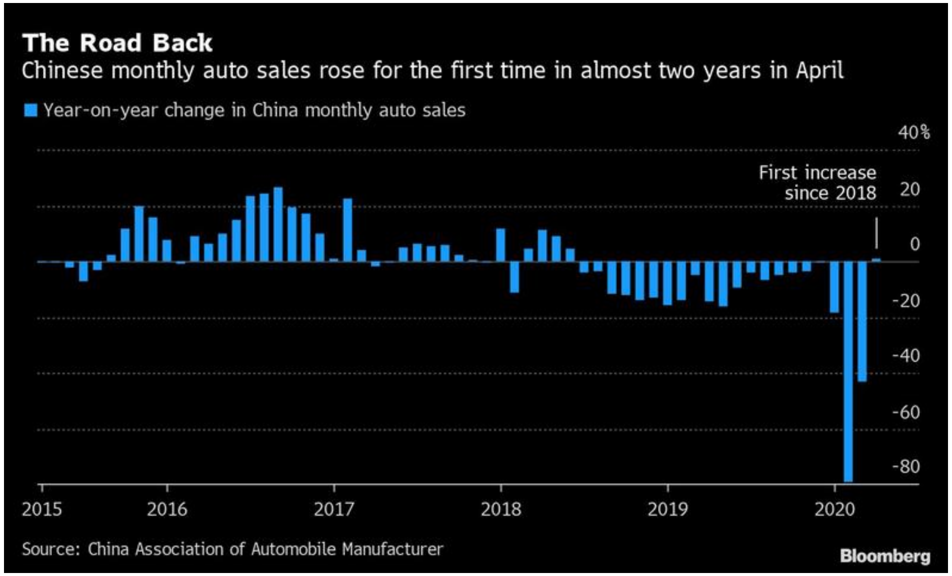
# How relevant is NEXTCAR today?



# NEXTCAR Program Level Results (to date)

- **Point 1** – bear in mind that results are vehicle-specific, vehicle duty cycle, traffic density, technology, penetration rate, weather specific.
- Not all efficiencies are additive, (but some are).
- These results are presented without context.
  - Results between teams and technologies are not directly comparable (see **Point 1** above).
  - Some results are simulated, some experimental (including HIL, DIL, on-road), some real-world…

# Potential Efficiency Improvements (%)

| NEXTCAR Technology | MTU | GM | OSU | SwRI | UD | UM | UCB | UMN | UCR |
|---|---|---|---|---|---|---|---|---|---|
| **Eco-Routing** | 2-21 | 7 | | 0-35*** | 7.7-13.8 | | 12.6-14 | 12.1 | |
| **Eco-AND** | 2-10 | 8 | 4-14 | 0-9.8 | 17.8 | | 31[2] | | 9.6-22.9 |
| **Eco-Driving/Cruise** | 1-7 | 10-14 | 13-16* | 10-13* | 20 | 12-14 | 6.8-15.8 | | 0-12.8 |
| **Powertrain Optimization** | 5-12[1] | | 2-4** | 4.9 | 12 | 2-7 | 9 | 20.1-21.8 | 8.5-10.5 |
| **Thermal System** | 4-7 | | | | | 2-8 | | | |
| **Compact Platooning** | 1-7 | | | | | | 0-15 | | |
| **Intelligent HVAC** | 1-28 | | | | | | | | |
| **CACC** | 1-6 | | | | 2.6-13 | | | | |
| **Eco-Stop and Launch (bus application)** | | | | | | | | | 10.9-22.9 |

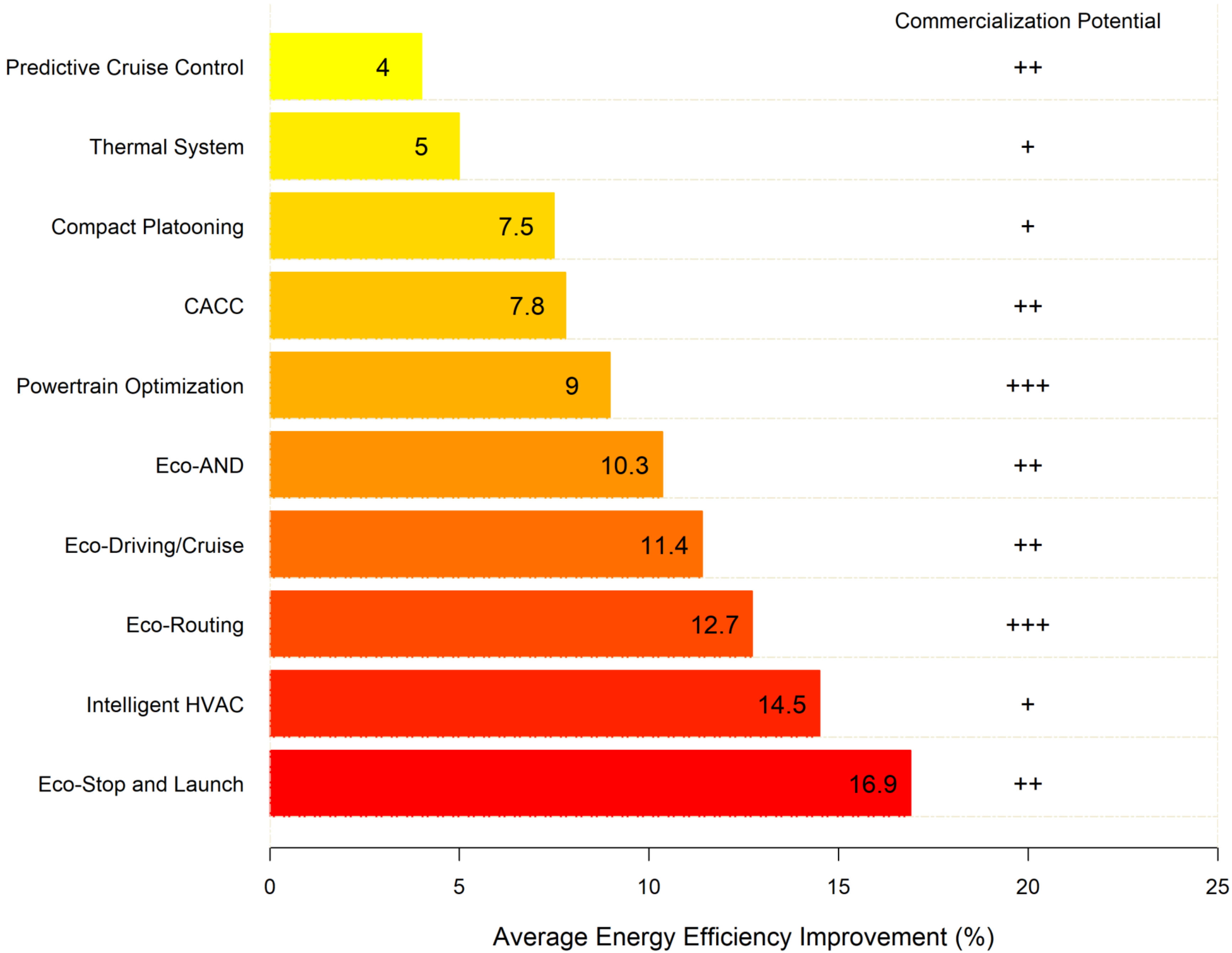
*Eco-driving does include power-split,** Indicates improvement only by leveraging dynamic skip firing (DSF), Eco-routing includes power-split optimization over the long horizon

[1]MTU powertrain optimization includes optimization of drive unit as well as PHEV blending

[2]Charge depleting mode, with an 8.5% increase in travel time on 2.5km arterial

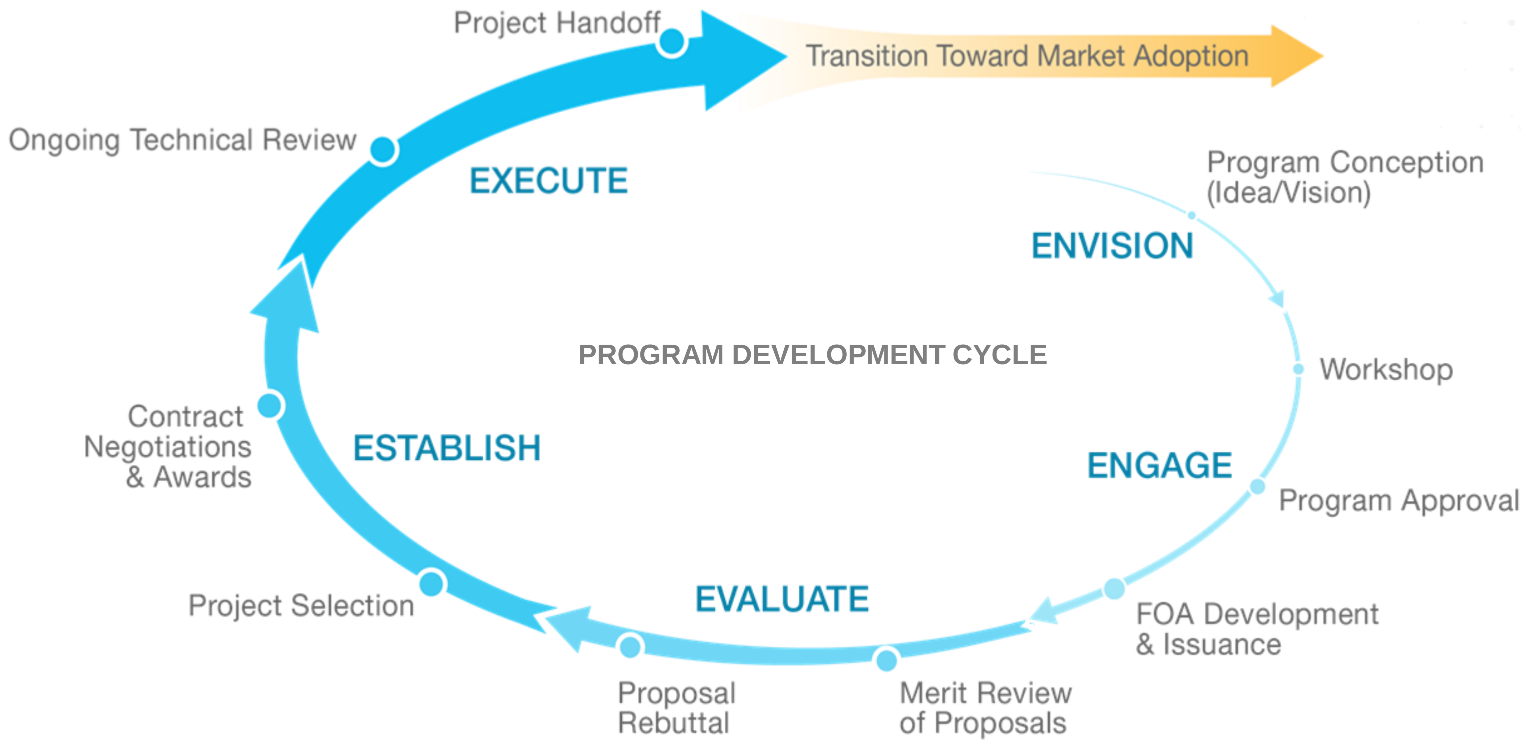


**Bear in mind Point 1!**



Commercialization Potential
Predictive Cruise Control
4
++
Thermal System
5
+
Compact Platooning
7.5
+
CACC
7.8
++
Powertrain Optimization
9
+++
Eco-AND
10.3
++
Eco-Driving/Cruise
11.4
++
Eco-Routing
12.7
+++
Intelligent HVAC
14.5
+
Eco-Stop and Launch
16.9
++
0
5
10
15
20
25
Average Energy Efficiency Improvement (%)

# Technology Acceleration Model



# NEXTCAR Summary

- NEXTCAR has achieved **significant results** across a range of technologies.
- The motivation for NEXTCAR is **more relevant** than ever right now.
- Commercialization success is the **next critical step**.

- NEXTCAR Field Demonstration Days in September/October at ACM?
- Other avenues for dissemination of information – conferences, workshops, papers, demonstrations?

- ARPA-E is always interested in energy efficiency technologies – anticipate OPEN 2021?

- *Bon voyage!* Be safe, be healthy and do good things. See you down the road.